RESUMED **[2.46 PM]**

COMMISSIONER: Being 2.45 we will reconvene with Dr Paul Ashley. Mr Jacobi.

MR JACOBI: Dr Paul Ashley is a consultant geologist with more than 40 years of professional experience and academia in industry and government organisations. He is currently employed by the University of New England and specialises in petrographic and mineralogical work and environment geochemistry. He holds an adjunct associate professor's position in Earth Science at that university where he formally taught and performed research in (indistinct) deposit geology, geochemistry and environmental geology amongst other topics. Dr Ashley has carried out studies in to the environmental impacts at several legacy mining sites, including Radium Hill and has had numerous papers published on those investigations, including that in relation to Radium Hill and we call Dr Paul Ashley to the commission.

COMMISSIONER: Thanks Paul. Thanks for coming back from your holiday, very much appreciate - - -

DR ASHLEY: Thank you for having me.

COMMISSIONER: Mr Jacobi.

MR JACOBI: I just wonder whether we might start – we are interested to understand the relationship between environmental outcomes from uranium mines in particular and wonder whether you might be able to offer some insight in terms of the relationship between the mineralogical formation and the environmental outcomes that you expect?

DR ASHLEY: Okay. Well, uranium occurs in nature in a number of different mineral forms and that often dictates the way that the – if you have natural concentrations of those minerals, they form an ore body and the mineralogy often dictates the way in which that ore material is treated. So for example there's a particular mineral that occurs in certain types of uranium ore bodies which you leach out with an alkaline solution and the product that you end up with there, the waste product you end up there will be quite different from say an ore deposit containing different uranium minerals that have an acid leach instead. So there are alkaline and acidic leaches and the environmental outcomes of those are quite different. Moreover, some of the different uranium minerals occur with different associated minerals and some of the uranium deposits have large amounts of what we call sulphide minerals associated with them and if they are mined and then exposed to the atmosphere and the water, well then sulphide minerals break down commonly and form what we term acid mine drainage, which was referred to earlier this afternoon. That itself then brings on a whole series of additional environmental problems in addition to management of uranium itself and management of the radionuclides from uranium.

MR JACOBI: If I can just pick up the first part of what you just explained in terms of the solvents you referred to – uses both bases - - -

DR ASHLEY: Yes.

MR JACOBI: - - - and acids. Are they relevant, and is that chemistry relevant both at a natural level as well as in terms of the extraction activities which, as I understand it, use both acids and bases?

DR ASHLEY: Yes, in a way. In the natural environment, uranium can be made quite soluble in acidic solutions. So if you have for example, the uranium ore body that contains sulphide minerals as well, and it's subject to atmospheric action, in other words, action of rain and air on it, well you can naturally produce acid from the oxidation or weathering of the ore material and that can mobilise uranium in to things like surface waters and ground waters. On the other hand, some uranium ores contain what we call refractory uranium minerals and they are essentially insoluble under all atmospheric conditions. That was largely the case at Radium Hill where the uranium mineral itself was really quite insoluble and there were no associated – or very little associated sulphide minerals with it. So therefore, uranium in the Radium Hill environment was really relatively immobile. It did not move around significantly, same surface waters which there was very little of, or in ground waters. So what I am getting at again, is the mineralogy of uranium dictates things like environmental mobility in the natural state and also when it's processed.

MR JACOBI: I am just wondering whether, by comparison to the refractory example of an ore that you have identified, whether there are some other examples of other commonly found ores that have different characteristics?

DR ASHLEY: Do you mean uranium ores or?

MR JACOBI: Yes. Sorry, uranium ores. That's right.

DR ASHLEY: Yes. Yes, well that's true. In northern Australia there are a number of well known examples that – say the Ranger uranium mine, the former Rum Jungle mine, the Mary Kathleen mine in north-west Queensland that each of those mineral deposits has had, or still has, significant amounts of sulphide minerals in it and that creates this possibility of acid production during mining. Moreover, those three examples I've mentioned are in significantly wetter climatic regimes than exist say in South Australia and the wet conditions, the amount of surface water at certain times of the year will, again, help uranium mobility in the environment.

MR JACOBI: Just as a distinction from being refractory, what is the nature of the ores at the deposits you have mentioned?

DR ASHLEY: At each of those deposits, the main uranium mineral is called uraninite, uranium oxide and it is really quite reactive when it comes to surface conditions. So it oxidises readily in the air and once it's oxidised it becomes more available for mobilisation in to ground water and surface water. And moreover, as I've mentioned before, each of those mineral deposits has sulphide minerals associated with it which on oxidation produces acid and the acid helps mobilise the uranium in to surface waters and ground waters.

MR JACOBI: Now to come to the particular ores that are found at Radium Hill, I think we've had Mr Kakoschke this morning refer to it as davidite.

DR ASHLEY: Mm'hm.

MR JACOBI: Is that the proper mineralogical name for that particular ore?

DR ASHLEY: It is. The ore at Radium Hill was actually a very complex material but most of it was refractory and as Kevin was mentioning this morning, it required acid, very strong acid dissolution to try and get the uranium in to solution - what happened here at Port Pirie. But yes, the uranium, main uranium ore mineral at Radium Hill was supposedly the mineral davidite which is a compound of uranium, titanium, iron, oxygen and a few other elements in with it. There was also other uranium minerals present, a mineral called brannerite which is a uranium, titanium oxide mineral. It is again, a refractory mineral that is really quite insoluble under surface conditions. So yes, the mineralogical form of uranium at Radium Hill differs quite considerably from let's say those mines I've mentioned in northern Australia. And it also differs considerably from say Olympic Dam. Although Olympic Dam is again, rather complex in terms of its uranium minerals.

MR JACOBI: Just so that the commission is clear and given the significance of Olympic Dam, from evidence that we have heard from other geologists in the course of the commission, what is the characteristic difference in terms of the ore, as compared to what's found at Radium Hill?

DR ASHLEY: At Olympic Dam there's a significant proportion of uranium in the mineral uraninite which is more soluble under environmental conditions. There is however a considerable amount there of the mineral brannerite at Olympic Dam and that is again, a more refractory mineral.

MR JACOBI: I am just wondering about whether you might explain the significance of the geochemistry in terms of, as I understand it, the uranium either being an oxidised or reduced state and whether that is significant in terms of the environmental outcomes?

DR ASHLEY: Yes, absolutely. At the Earth's surface uranium minerals tend to oxidise slowly or rapidly depending on the original primary mineral and they react with oxygen in the atmosphere and make uranium compounds which are more soluble in water. If there was an absence of oxygen, if – in other words, if they're down under the ground, uranium is mostly what we call the more reduced form as opposed to the oxidised form at the Earth's surface and in the reduced form, uranium is essentially immobile in things like ground waters. So that you could have a mineral deposit like Radium Hill in which most of the uranium is in the reduced form, no oxygen and in contact with ground waters there, it's essentially immobile, so there would be very little – so uranium dispersion in to the ground waters. On the other hand, at the Earth's surface if you get uranium in the oxidised form, after reaction with atmospheric oxygen, it becomes quite soluble in compounds involving carbon dioxide. In other words, atmospheric CO2 can help mobilise uranium in the oxidised form. Uranium is also very soluble in acids, particularly sulphuric acid. Certain other acids are very soluble. So if you have got a combination of acid and oxygen, in other words, the atmosphere, uranium can be very mobile and it will disperse in solution in surface waters and it can also obviously contaminate ground waters.

You might put it another way though, that under surface conditions where uranium is quite mobile, if those waters come in to contact with less oxidising conditions, if they for example seep in to a wetland environment, if I can use the term swamp or something like that, a mangrove swamp, that sort of thing, there's a change from oxidised to reduced and under those conditions, uranium will precipitate out and it will become immobilised. So this morning there was a mention of the example of the tailings dam at Radium Hill and the possibility of marine contamination. I would predict from a geochemical viewpoint that in the tailings dams here, most of the uranium is in the oxidised form and it's probably quite mobile and it can seep in to ground waters. However, if that ground water then seeped out in to the former marine clay that was mentioned this morning, and out towards the marine environment, it would become immobilised because it would change from oxidised to reduced and under reduced conditions, uranium is effectively insoluble. So my prediction would be that there would be potentially little effect from the seepage of uranium from the tailings dams here, in to the marine environment because of what we call is a red ox barrier, oxidation reduction barrier.

MR JACOBI: Is that essentially because of the characteristically alkaline characteristics of that mangrove environment?

DR ASHLEY: It's because of the lack of oxygen. Yes. And the presence of gases in that reduced environment such as methane, hydrogen sulphide, those sorts of things tend to immobilise uranium virtually instantly. I might also add that the so-called in situ leach deposits that South Australia has a number of operating or formerly operating examples, the formation of those sorts of deposits is again based on oxidation and reduction and what the ISL process is doing, is effectively reversing the natural process, so it’s going from reduced to oxidised, you pump down a solution that is oxidising and acidic and you leach out the uranium. So you are basically reversing what nature had done in the first place to concentrate the uranium.

MR JACOBI: And that is transitioning it from being immobile to being mobile?

DR ASHLEY: Correct.

MR JACOBI: And can I – we have heard about the range of other heavy metals that are associated with – particularly the tailings that we were discussing today and I’m just interested in taking a step backwards in terms of the metals and other products that are commonly associated with uranium.

DR ASHLEY: Mm.

MR JACOBI: I’m just interested to understand, are there particular metals that on expects to find within uranium ores?

DR ASHLEY: Yes. There are several different types of uranium ores which I put in my report and there are some particular associations in nature. One of the strong ones is the uranium associated with the element vanadium, another one or another group of them is uranium associated with gold, as well as with elements like copper, lead, zinc. Some of the Canadian examples that were mentioned this morning of Saskatchewan – sorry, earlier this afternoon, Saskatchewan and in that province in Canada there's a strong association between uranium, arsenic and nickel, for example. That's a particular association.

In the case of Radium Hill, uranium occurred mostly by itself, but it did have the element titanium strongly associated with it, which is an environmental benign element. There's really no toxic effects or anything from titanium. Rare earth elements are strongly associated at Radium Hill. Scandium, which was mentioned this morning, again probably an element that has got not toxicological effects at all. And I guess a final element that is commonly associated with uranium, a good example in South Australia is the Crocker Well deposit north of Manna Hill with uranium and thorium, and as we know, thorium is again another radioactive element and, yes, potential nuclear fuel source for the future.

So to summarise, there are a number of different associations, some of which are environmentally sensitive elements like arsenic, copper, lead, zinc, vanadium perhaps in some cases, and I think the element selenium is another one that sometimes occurs and it has some environmental negativity about it.

MR JACOBI: Can I come to deal with the relationship between the hydrogeology and the environmental impacts, and I think we've already had some discussion about the potential for uranium to intrude upon groundwaters, and I'm just interested in thinking about the extent to which hydrogeology is relevant to the - and the hydrogeology is relevant to the sorts of environmental outcomes that you expect.

DR ASHLEY: Yes. I guess the most important one is related to the climatic regime. So in a wet climate or a seasonally wet climate where there are a large amounts of surface water and therefore potentially affecting groundwater, that creates a significantly large problem in water management and if some of the uranium is made soluble into that surface groundwater by reaction with the atmosphere or reaction with, sorry, acid-proceeding minerals, then that creates a significantly large problem with water management.

In dry climatic areas, however, it's - I think the hydrology aspect is far less of a problem, and I think in the case of Radium Hill, the watertable there is quite deep. There's essentially no surface water except in rare heavy rain events, and there's effectively no acid mine drainage there at all. The hydrology depends really on the water balance, how much water there is, and it's obviously a much greater management problem in wet climatic areas. The Range uranium mine would be a superb example.

MR JACOBI: In terms of the water at Radium Hill, the water that's deep, what's the quality of that?

DR ASHLEY: Kevin would probably have a much better idea than I, but in my experience in the general Olary region, most of the water is so saline that it's marginal for stock quality. So, yes, it ranges between, let's say, brackish and saline, probably between about 5,000 and 14,000 parts per million, which is almost half seawater concentration. Just another comment on groundwater, in the small map of experience I've had on the Honeymoon uranium deposit, again the water there is highly saline. I think it was about 2% salts and that's far above the level that would be used for, say, stock watering purposes.

MR JACOBI: And coming to the question of arid regions and the regions that we particularly considered about for Radium Hill, what are the environmental considerations that apply there and what are the environmental factors that drive potential disbursal?

DR ASHLEY: Well, as Kevin has mentioned this morning, the two really important factors are wind and water. Something that tends to be downplayed, I think, in people's understanding of arid and semi-arid environments is the importance of water as a disbursing mechanism, and the fact that the tailings storage facilities at Radium Hill have been quite badly damaged by water erosion since they were capped in the early 1980s is testament to the power of water there. On the other hand, when the TSF, tailings storage facility, there was - the main facility was uncapped. Obviously wind erosion was a very important factor there, and that was important solely because of the fine particle size of the tailings material.

The particle size was generally less than 1 millimetre, and a lot of the mineral particles were in fact flaky mica particles which were - they're easily lifted by the wind and easily disbursed. So it depends on the particle size of the tailings material, and also the mineralogical form of the tailings material, as to how easily disbursed they are by wind action, but I think it's those factors that allowed the wind dispersion to be important in the early days. After capping of the main TSF, the main dispersion factor there has been water. Yes.

MR JACOBI: I think perhaps before we come to deal with the specific environmental issues you've identified Radium Hill, I just wondered whether you could explain - and you published an article with Bernd Lottermoser concerned with a review that you'd done at Radium Hill. I'm just interested, could you explain the circumstances in which you came to do that particular piece of work?

DR ASHLEY: I'm not quite sure of the paper you're thinking of, but the main paper that was important, in my understanding, was the paper in the Australian Journal of Earth Sciences, and there was a subsequent paper that was - - -

MR JACOBI: Yes, a paper titled Physical Dispersion of Radioactive Mine Waste at the Radium Hill Uranium Site?

DR ASHLEY: Yes. That came about because Bernd and I had had some prior experience in assessing the environmental situation at the Mary Kathleen uranium mine in northwest Queensland. We'd done that work in 1999, 2000, and the essence was that Bernd became very interested in assessing the engineering, let's say, quality of rehabilitation, what had been carried out in previous years and he got a significant grant to carry out the work at Mary Kathleen, and we then came to the conclusion that the Radium Hill deposited was in a different climatic regime and had a different set of circumstances, and so we applied for some funding for that and we obtained some small grants to come and study here in South Australia.

And just to compare and contrast the different climatic and topographic regimes, similarly there was a difference in the type of uranium mineralisation. So Radium Hill represented a type of in which the ore was refractory and there was essentially no chemical dispersion here where it's mostly a physical dispersion by wind and water, whereas at Radium Hill the ore mineral there was mostly uraninite which is more soluble, and there were also sulphide minerals present at Mary Kathleen which made a bit of acid mine drainage. So it was just an interesting comparison and contrast between those two deposits and that true us into Radium Hill.

MR JACOBI: So you visited Radium Hill for the purposes of undertaking that study?

DR ASHLEY: That was correct. I had some previous experience at Radium Hill. I'd worked in the Olary region on and off since 1977 as an exploration geologist, and then during research at the University of New England, and I must admit, go to Radium Hill in 1978 before the main TSF was capped and I was, let's say, a bit bemused by the bluey, grey dust blowing off in the wind at that stage. Subsequently, when we did come back and do the research project on it, it was all different. It was all capped then, but in that intervening 20 years between 1981, whenever it was, and 2002 when we did the research project there, there had been enough water erosion there to expose significant amounts of tailings again.

MR JACOBI: We've got some slides that assist us in explaining what you consider the environmental issues at Radium Hill to be, and perhaps we can work our through them. As I understand it, many of these are images that were taken for the purpose of your study in about 2002, 2003?

DR ASHLEY: Most of these were. Wes sent me some recent photographs that you had taken when you visited there in August and you will probably recognise some of those in this presentation as well but some certainly date from 2002.

MR JACOBI: Perhaps if we can go to the first slide. Can you give us an indication to the year in which that – what year that image shows?

DR ASHLEY: We obtained this image from Purser in about 2004. I understand the photography was taken either that year, or within the previous two years. So let’s say early 2000’s. It post-dates the 1997 flood that Kevin was mentioning this morning, in that the stream coming down the eastern side of the mine site and parts of the industrial site there, had probably washed away some of the surface material and - - -

MR JACOBI: So just as a matter of orientation, what I think this morning was left to right is not top to bottom.

DR ASHLEY: Yes.

MR JACOBI: Yes.

DR ASHLEY: Yes. Just a bit of geography here, this is the area that Kevin was mentioning this morning, the industrial site and there is the main TSF there. The town site is over here.

MR JACOBI: That is in the top left of the image?

DR ASHLEY: The top left. This is Olary Creek which is the main drainage that would catch all the drainage coming from the site.

MR JACOBI: I think perhaps go to the next slide. You had identified at that point, some key characteristics of the site, even as it existed in 2003?

DR ASHLEY: Mm.

MR JACOBI: Could you explain what they are?

DR ASHLEY: Yes. So this is just a blow up of the previous image. Here is the industrial site up in here, the former workshops, processing plant, there are a number of what we called waste rock dumps. And as Kevin said this morning, there were different types of dump material, rock dump material there which is different particle size. There were what we call fine crush and course crush, so this type of material here was quite course material. This is quite course material. The fine crush material was – let's say particle size of two centimetres or less and that was used to make concrete and road surfacing et cetera. This big rectangular body here is the main tailings storage facility. The dimensions of that are about 250 metres by 150 metres and on average, about six metres thick. In terms of total volume, there's about close on 250,000 cubic metres of material there and if one assumes a specific gravity of about two or two and a bit there's probably a bit over half a million tonnes of material in that main TSF. There's some smaller TSF there, that pale coloured one and Kevin could probably identify some other ones. But I guess the collective amount of tailings that are there is probably in the order of a bit over half a million tonnes.

You will notice the greyish colour dispersion around it and this is due to the wind dispersion, pre-capping in 1981 and that is a prominent feature. The black line represents the original outcrop of the so-called line of load of the original outcropping of the Radium Hill ore deposit and there are still some pits along that in which you can find high-grade uranium, varying rocks sticking out of the ground. Just think maybe the next slide might have that actually on it. Just some of the – that is a pit along that line of load, there's natural – well, it's not natural but it's near the natural surface and this dark material is here is some of the uranium mineralisation at the Earth's surface. Very high radiometric count coming off that, if you go there with a gigacount.

MR JACOBI: Could I just explore that with you for just a moment? To what extent is there near the surface, or at the surface, in fact the ore body that they were seeking to mine? Is that characteristic of that particular area?

DR ASHLEY: Yes. If you have a refractory uranium deposit, the minerals are really fairly stable at the Earth's surface and so the will effectively crop out at the Earth's surface. That is in contrast to certain other types of uranium minerals which react with the atmosphere and you will find what we call secondary minerals at the Earth's surface. So the mineral deposit at Radium Hill is mainly formed at these dark, black coloured minerals, as you can see in the outcrop there. But there are other mineral deposits in the world, for example the Ranger uranium deposit in the Northern Territory, or the Narbelic(?) deposit in the Northern Territory, if you expose that uranium mineral to the atmosphere, to the air and water, the dark coloured uranium mineral reacts with the air and the water and it forms generally a brightly coloured, what we call a secondary mineral which is stable in the Earth's atmosphere. And those secondary uranium minerals are usually bright yellow, orangey yellow or green in colour and so at Radium Hill there's just a little bit of that oxidation going on and there's some of the lumps of rock there in the shovel that have got this yellow coating on them, and that's due to the slow reaction of the natural uranium bearing mineral under the ground, with the Earth's atmosphere.

MR JACOBI: Are there many such outcrops around the Radium Hill site?

DR ASHLEY: No. There are – if you go just over the border towards Broken Hill, there's some outcrops of similar material at Thackaringa which look a bit similar to that but the only other place I've seen in that part of world is a Crockers Well, north of Manna Hill where there's actually the uranium mineral is actually exposed at the Earth's surface and because it's one of these so-called refractory uranium minerals, it's just sitting there at the Earth's surface and not doing anything apart from giving off radioactivity.

MR JACOBI: I think our next image, we've already talked about the waste rock and just wonder whether you could - - -

DR ASHLEY: Yes. That's typical of some of the just coarse waste rock materials piled up in various dumps. The next one, I think shows a similar type of thing. That is more crushed rock. The particle size of that is in the order of a few centimetre and interestingly the – some of these crushed rock waste dumps have got pepper trees growing on them, which obviously date from the time of the town at Radium Hill. We sampled the pepper tree leaves and saltbush above ground biomass of saltbush and analysed those biological materials that were growing on contaminated ground and found that in comparison to so-called background regions, that's a kilometre or two away, that there was significant uptake of uranium and certain other elements in to the biomass of those plants. So you sort of then wonder about if animals go and eat those plants growing on contaminated areas, that they have a – there's a potential pathway for radioactive elements and radionuclides to get in to those plants. But to put it in to context, the area of contamination at Radium Hill is really quite tiny; it's probably in the order of a few hundred to a few thousand of square kilometres. And if you say imagined a kangaroo going and nibbling on some saltbush or something like that, the kangaroos is not specifically going to go to those contaminated areas to graze. It will probably have a wide grazing region and it will be diluting any effects of ingesting contaminated plant material.

MR JACOBI: I think you just said then a few hundred or a few thousand square kilometres?

DR ASHLEY: No, metres. Yes.

MR JACOBI: I just wonder whether perhaps we can come to the next slide, just move on the next one and come to the radiometric – I'm just interested whether you could explain the significance in your interpretation of that?

DR ASHLEY: Yes. This is an image that's created from an aircraft flying over the landscape at a height of generally about 80 metres and in the aircraft there is a detector that – it's called a spectrometer that detects different wavelengths of radiation coming from the Earth's surface. This one here is called the uranium channel, so it's picking up the characteristic radiation wavelength of uranium. But you can also get a similar image if you put it on the – what's called the thorium channel and pick up – detect thorium and you can also do the same for the element potassium which is also radioactive. So this particular one is just focussed in on the uranium channel and it shows what we would term to be radiometric anomalies at the earth's surface. So the background is this area out here and that will have relatively low levels of uranium in it.

MR JACOBI: That's the area shown in blue?

DR ASHLEY: In blue and green, yes. The mine site area, big blob of red there, and the distance across that mine site region is probably in the order of at least 4 square kilometres, 4 or 5 square kilometres, and here's the township site over here, which is a somewhat similar size. That's the road going between the town and the mine. Clearly it was paved with radioactive crushed rock. There's another one going off to the northeast. That was the road that joined the township with the road came into Radium Hill. Another image that I wasn't able to show, but it's taken further north of that and it shows the radiometric line going across the landscape, probably up here somewhere, which was the ballast on the railway line that was, again, sourced from Radium Hill, and that's a prominent straight line across the landscape.

I should add that in the mine site area some of this is natural. There was an original outcrop of uranium-bearing rocks at the earth's surface and that would've given a natural anomaly there. However, it's clearly obvious that there's been significant dispersion away from the original outcrop site, and so where the TSF is there you can see that there's been probably significant dispersion by wind and water to the east and south. And the township region there, I would say that just about all of that anomaly over there is anthropogenic. It's been placed there.

MR JACOBI: In terms of the extent to which that is radioactive, you undertook measurements at the time?

DR ASHLEY: Yes, we did. We had a spectrometer with us that measured the different types of radioactivity, and in a nutshell, the levels there are low and that, as was mentioned earlier today, for a normal visitation there for, say, members of the public or scientists going there to have a look, there's no hazard whatsoever. The measurements in millisieverts per annum is really infinitesimally low. The highest readings that we got were on some of the eroded tailings storage facilities, and when you calculate it out on an angle basis, the highest readings we got were about 40 millisieverts per annum, which is certainly quite above the average amount that an Australian would get naturally. It's about 20 times what people would obtain naturally. But that's on the basis of you being physically attached to that tailings storage facility for a whole year. And so you can see the sort of ridiculous nature of that, that it's - when you have a casual visitation there, there is essentially - your increased dosage would be infinitesimally small.

MR JACOBI: I think our next image might show some of the concrete structures that you - - -

DR ASHLEY: Yes. The fine crushed material was extensively used at Radium Hill to make concrete. So most of the major concrete structures are mildly radioactive. It was used, as you've seen before, for road construction. Bitumen roads had the same radioactive gravel used, and - sorry, I was going to mention railway ballast was the other form, but, yes, essentially there's been quite widespread use of this low-level radioactive waste rock.

MR JACOBI: I think we've already dealt with - and I think this might show up quite clearly - the extent to which the tailings certainly can erode.

DR ASHLEY: Yes.

MR JACOBI: I'm just wondering if you could point out the key features of that.

DR ASHLEY: Yes. The most important thing is that the main TSF here, although it was allegedly capped with a metre of soil, and again, a significant thickness of material on the sides of it, it's clear that the coverage on the steep sides is quite insufficient to armour the TSF from erosion, and our causal observations there were that the maximum amount of soil that was placed over the sides was probably no more than 30 or 40 centimetres, and as was mentioned by the gentleman earlier on this afternoon, most of it's almost at the angle of repose. It's sort of between 30 and 35 degrees, and it's difficult to get loose soil to hang up there on that sort of slope.

So consequently, with water erosion and the type of erosion that Kevin was mentioning this morning about if you had a couple of hundred millimetres of rain falling in one day, the erosive power of that is just extreme, and that's what's caused this rilling effect down the side of the main TSF, and that's re-exposing the tailings to the atmosphere. Because of the armouring by the soil at the top of the TSF, there's effectively no wind erosion happening at the moment, but there's certainly water erosion taking place. I think the next slide might show a more extreme example of - that's a similar thing. That's on the top looking along at - perhaps the next one.

Yes. That's one of the small tailings storage facilities and that one actually had one of the highest readings that we obtained from the tailings material. The uranium concentration in that material was as high as 1,600 parts per million uranium, so that's basically ore-grade material. That could be economic at the moment. And that stuff has been exposed by water erosion there.

MR JACOBI: You referred to that as being one of the small tailings facilities. That's not (indistinct)

DR ASHLEY: That's not the large one, no. That's one of the small ones, but that material there was certainly the highest in terms of radioactivity and total uranium content.

MR JACOBI: I think the next slides might show what we've discussed in terms of wind disbursal.

DR ASHLEY: Yes. This is a legacy of the lack of capping until 1981, and there was obviously significant loss of tailings by wind erosion in the period between, let's say, 1961 and 1981. Probably several tens of thousands of tonnes of material has been disbursed by wind to the east through to the south of the main TSF, and in places it's so thick that it's built up into small dunes, and that material typically contains between 200 and 300 parts per million uranium, so it's about 100 times background and it's quite radioactive. And it's still mobile at the moment. Clearly that could be blown by wind and it's certainly easily mobilised by water.

I think the next one or two show - that's just a general view from the top of the main TSF, looking to the southeast and showing the fact that the wind erosion has disbursed the fine tailings up to about 700 metres away. And there's relatively high radiation levels, up to ten times background, close to the main TSF, and as that picture there shows, there's a number of other elements that are disbursed with uranium. The first two there are rare earth elements, then there's scandium, a little bit of thorium, and then there's vanadium and yttrium. The only one that's of significant environmental concern there is of course uranium. The other elements are either environmentally benign or at levels that are environmentally inconsequential.

MR JACOBI: And I think perhaps we come to the last, which might be the one - - -

DR ASHLEY: Yes. They're just pictures of the tailings sitting on the soil. I think the last picture there is more a graphical representation. That's the last one, just showing - we took some soils samples leading to the southeast from the main tailings storage facility. So on the left-hand side of that graph is the position of the main TSF, and as you went away to the south, southeast, a distance of seven or 800 metres there, you can see the change in the concentration of these different elements and the black line there is – I think it’s black, dark blue line there is the uranium concentrations that you can see. Going from perhaps a maximum of two or 300 parts per million down to 10 parts per million when you go seven or 800 metres away. The regional background in the Radium Hill area is between about five and 10 parts per million. That’s the natural background. So you can see it takes best part of a kilometre to get down to - - -

MR JACOBI: And is that in the direction of the prevailing wind? So south, south-east?

DR ASHLEY: That’s – well, it’s the opposite, the prevailing winds - - -

MR JACOBI: Yes, sorry.

DR ASHLEY: - - - were coming from the west and the north, north-west, so yes.

MR JACOBI: The question for the commission to consider is what are the lessons to be learned and I’m just interested to hear your view as to what you think the lessons are that emerge from what has happened, and the way that it was managed in terms of other activities that might be carried out in a similar climatic environment?

DR ASHLEY: Yes. Look I think some of this was sort of touched on this morning because of the imperatives of the time were to carry out a fairly lean and mean mining operation and have it perform safely. And those in the 1950s there were essentially no environmental regulations that were pursued. That was all carried out very successfully in terms of the mining and milling operations. However, the lessons that can be learnt from that, and I guess this is something that has evolved over the past 50 years, and obviously probably the most important one there is tailing storage management. Under the particular climatic regime at Radium Hill, the fact that the main TSF was allowed to dry out and was then subject to wind erosion and water erosion, that was a lesson that I think just about any responsible minor in the past several decades would have learnt from that experience. So tailing storage management is critical.

I might just turn to say the example at Mary Kathleen which we worked on in the period just before the Radium Hill study. Mary Kathleen was decommissioned about 1984, 1985 and let's say that was best part of quarter of a century after Radium Hill finished and in that period the environmental constraints that were placed on rehabilitation had tightened up, or were at least applied and then tightened up considerably and the management of tailings at Mary Kathleen was a complete, let's say paradigm shift away from what had happened at Radium Hill quarter of a century before. So the tailing storage facility was well managed, it was put down in a topographically low area, it was managed to be topographically flat with the rest of the landscape. It was armoured with thick rock barriers, it was covered with two metres of rock and then soil and then had native vegetation put over the top and the predictions were that that would be a stable landform for the foreseeable future. Meaning hundreds to perhaps more than a 1,000 years.

Now clearly at the Radium Hill example, none of that was considered, there were no environmental considerations at all. The capping of the TSF at Radium Hill in 1981, again there was complete lack of understanding of the long-term stability of that structure and you can see that in the subsequent 20 years, the amount of real erosion that took place there is just testament to the lack of understanding of what the parameters were there. Maybe that was partly driven by the funding situation at the time that perhaps there was limited funding to carry out proper rehabilitation but I think there are lessons to learnt there on, if you're going to do a rehabilitation job, do it properly in the first place because clearly there's a huge difference between the Radium Hill situation and let's say a much better managed example at Mary Kathleen. Certainly Mary K is not perfect by any means but it's certainly a stable landform that will last for a long time.

Some other lessons are don't use waste rock that contains significant uranium for purposes such as building construction where people are going to live and work. Even the use of it on roads and railways, one would consider it perhaps inappropriate these days. I guess some other lessons that are not really applicable to Radium Hill but certainly the understanding of the production of acid mine drainage in uranium mine sites, that's quite critical. So if you've got the potential to produce acid during or after mining operations, understanding of that phenomenon is absolutely critical because acid mine drainage is – it's a real nuisance in it's own right but if it's got uranium and dissolved radionuclides in it as well, well then it adds a completely new dimension to how environmentally difficult it is to manage.

MR JACOBI: Do you have a view about the waste rock dumps that we've seen a number of the images in terms of how that should be managed, aside from the tailings generally?

DR ASHLEY: The waste rock dumps at Radium Hill, although they are radioactive and they contain let's say between probably up to 200 to 400 parts per million uranium, there is no acid production from them, so there's very – extremely low sulphide content of them, so there's effectively no significance there in terms of acid mine drainage from them. They are well ventilated, so that even though they may be producing small amounts of radon gas from them, there's enough wind and air passage there to make it a complete trivial amount of potential danger there from radiation from radon gas.

MR JACOBI: And what about the – move away from the waste rock dumps, what about top soil? In terms of the top soil that's moved?

DR ASHLEY: Well, again the contaminated top soil there, the levels of uranium in the top soil are, again, the maximum values that are right next to the TSF, probably up to two or 300 parts per million, and then as the graph there shows, when you go to distances of a few hundred metres it's starting to get down towards background levels. There could be some case for trying to – at Radium Hill trying to scrape up the worst of that wind blown material, close to the TSF and essentially bury it under a better-constructed facility. But I think I suggested in the report that maybe some sort of ploughing of the land there to mix the surface tailings material with the soil, basically to dilute the effect, that would be an appropriate mechanism. But in that dry climate, subject to wind and water erosion, you've got a problem there I think of revegetating the landscape. Revegetating would be good to stabilise the land but land managers would have a challenge there I think, so - - -

MR JACOBI: Because of the environmental conditions in terms of - - -

DR ASHLEY: Yes.

COMMISSIONER: Dr Ashley, thank you very much. We will adjourn.

DR ASHLEY: Been a pleasure, thank you.

COMMISSIONER: Next week.

MATTER ADJOURNED AT 3.38 PM ACCORDINGLY